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VARIATION OF SUGAR CONTENT IN VARIOUS PARTS OF PITAYA FRUIT

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Abstract. **Pitaya (*Hylocereus undatus* Britt & Rose) belongs to the Cactaceae family and is native of arid and semiarid regions. Pitaya fruit are edible and juicy with solids content in the range of 17 to 19.5 degrees Brix in the core part of the fruit. The soluble solids and enzyme activities in core, stylar-end, stem-end, and peripheral parts of the fruit were determined for red and white pitaya species. The predominant sugars in the fruit are glucose and fructose with small amount of sucrose. The patterns of sugar distribution in various parts were closely related to invertase and amylase activities in the tissues. A high ratio of glucose to fructose was attributed to the hydrolysis of starch by amylase. Pitaya fruits are a good sources of minerals, glucose, fructose, dietary fiber, and vitamins. Because pitaya can withstand prolonged drought, it is considered a potential economic crop for semiarid regions.**

Pitaya (*Hylocereus undatus* Britt & Rose) is in the Cactaceae family and is native of arid and semiarid regions (Morton, 1987). The pitaya plant produces edible and juicy fruit. The fruit is a berry with a thick wall (or peel) enclosing delicately flavored and seedy pulp. The peel color can either be pink, red, or light yellow and the flesh is either white or red color. Pitaya fruit is nutritious, drought resistant, and can tolerate low storage temperature (Morton, 1987; Campos-Hugueny et al, 1986). Commercial production of pitaya fruit flourishes in Mexico, Central America, West Indonesia Island, and Vietnam.

Pitaya cultivation has been recently introduced and fruit consumption has gained popularity in Taiwan. Previous work on pitaya fruit (Chang and Yen, 1997) showed there were large differences in soluble solids among various parts of the fruit. Pitaya solids contents range from 17 to 19.5 degrees Brix in the core part of the fruit with the predominant soluble sugars being glucose and fructose. Sweetness is an important quality attribute for consumer preference. Acid and neutral invertase (β-fructo-furanoside fructohydrolase E.C.3.2.1.26) are widely distributed in higher plants (Bradshaw et al., 1970; Richardson et al., 1990). Increased invertase activity is usually associated with an increase in hexoses and a decrease in sucrose (Pressey and Shaw, 1996).

The objective of this study was to investigate sugar distribution in core, stylar-end, stem-end, and peripheral parts of the flesh and their relationships with invertase and amylase activities in the tissues for red and white species of pitaya fruits.

Material and Methods

Fruit samples. White pitaya fruits were harvested form an experimental orchard at the National Pingtung University of Science and Technology. Red pitaya fruits were harvested from a commercial orchard in Taichung. The fruits were hand picked 50 days after flowering and the flesh separated into core, stylar-end, stem-end, and peripheral parts. The test samples were taken from the 1.5 cm-diameter cylinders from each section, then weighed, frozen, and stored at -18°C. Flesh of core, stylar-end, stem-end, and peripheral parts (5 g each) were homogenized separately with 60 ml of 90% (V/V) ethanol and clarified by centrifugation. After standing for 2 wk at -12°C, a 10 ml aliquot of clear supernatant of the homogenized samples was evaporated to dryness under a stream of N2 and redissolved in 5 ml of deionized water. Triplicate samples were used for analysis.

Sugar analysis. Glucose, fructose, and sucrose were measured enzymatically using the methods of Bergmeyer et al. (1974). Glucose was converted to glucose-6-phosphate (G-6-P) and to gluconate-6-phosphate accompanied by reduction of $NADP^+$ to NADPH. Fructose was first converted to fructose-6-phosphate, then to glucose-6-phosphate by glucose isomerase. Sucrose was first converted into glucose and fructose by β-fructosidase. The resulting solutions were measured by a Spectrophotometer at 340 nm.

Assay for invertase and amylase. The separated part of pitaya fruit flesh (10 g) was homogenized with a Polytron in 10 ml of homogenization buffer containing 200 mm HEPES (pH 7.8), 2 mm EDTA, 1 mm Mg-acetate, and 200 mM DTT. The extract was filtered through a 500 μm nylon cheesecloth and centrifuged (18,000 g for 30 min at 0-5°C) and then stored at -4°C (Kuti and Galloway, 1994; Bonvehi and Rosua, 1996); the supernatant was dialyzed vs buffer overnight. Aliquots of the extract were subsequently used for the invertase and amylase assays. Acid invertase activity was determined at pH 5.0 and neutral activity at pH 7.0 (Hubbard et al., 1991). Enzyme assays were done according to the procedure of Xu et al. (1989). Sucrose, 50 mm, was added to incubation buffers (70 mm K_2HPO_4/40 mm citrate for acid invertase and 160 mm K_2HPO_4/20 mm citrate for neutral invertase) containing fruit tissue samples. The reaction was allowed to proceed for 15 min at 25°C. Reactions were stopped by immersing samples in boiling water for 10 min. Prior to boiling the acid invertase samples, 15 ml of 0.1 M NaOH was added to each sample to neutralize the pH. Invertase and amylose activities were determined using methods of Mowlah and Itoo (1982). Soluble starch, 1% was added to the incubation buffer, pH 5.0 (70 mm K_2HPO_4/40 mm citrate) (final volume), containing fruit tissue samples. The reaction was allowed to process for 3 min at 30°C. Reactions were stopped by immersing samples in boiling water for 10 min. Prior to boiling the amylase samples, 15 ml of 0.1 M NaOH was added to each sample to neutralize the pH. Determination of protein concentration followed the method of Bradford (1976).

Results and Discussion

The measured soluble solids in various parts of the pitaya fruit are presented in Table 1. The results showed the solids content were in descendent order: the core, stylar-end, stem-end, and peripheral parts for both white and red pitaya species. In general, the white species had a higher soluble solid content than that of the red species.

Glucose, fructose, and sucrose were the major soluble sugars in the flesh of pitaya fruit; the content of sucrose accounting for only 2.8 to 7.5% of the total sugars. Glucose to fructose ratios for white and red species were 1.5 to 1.8 and 1.2 to 1.4, respectively. The results are presented in Table 2. In the white pitaya, for example, the sum of glucose, fructose, and sucrose varied in the range of 111.9 mg/g, 144.1 mg/g, 127.9 mg/g, and 174.4 mg/g in the peripheral, stylar-end, stem-end, and core parts, respectively. Comparing these values with the solids content in the corresponding parts (Table 1), it indicated there was a definitive relation between soluble solids content and soluble sugars in the fruit. Similar results are shown for the red pitaya.

The results in Table 2 also showed pitaya contained more glucose than fructose and the ratios of glucose to fructose varied in different parts of the fruit. In the white pitaya, the ratios of glucose to fructose were 1.6, 1.8, 1.5, and 1.6 in the peripheral, stylar-end, stem-end, and core parts, respectively. Similarly, in the red pitaya, the ratios of glucose to fructose were 1.3, 1.4, 1.2, and 1.37 in the peripheral, stylar-end, stem-end, and core parts, respectively. The distribution orders are similar in both species. As a comparison, in the pulp of prickly pear fruit, glucose, and fructose were present in almost equal amounts (1:1 ratio) (Kuti and Galloway, 1994). It was suggested that the invertase is a contribution factor in the conversion of sucrose to a same amount of glucose and fructose accumulation (Takahata et al., 1996); but, in the pitaya, the glucose and fructose were present in different amounts, suggesting that amylase may play an important role in the pitaya metabolism.

The measured acid invertase activities are presented in Table 3. The results showed the red species had the higher acid and total invertase activity compared with that of white

Table 1. Distribution of soluble solids in fruit flesh of two pitaya species.

Pitaya species	Portion of flesh	Soluble solids[z]
White flesh	Peripheral part	12.0 ± 1.2
	Stylar-end part	15.4 ± 1.6
	Stem-end part	13.6 ± 1.7
	Core part	18.3 ± 1.6
Red flesh	Peripheral part	9.1 ± 1.0
	Stylar-end part	11.7 ± 1.5
	Stem-end part	10.1 ± 1.2
	Core part	13.5 ± 1.4

[z]Values are the means of triplicate determinations ± standard deviation.

Table 2. Quantitative determination of sugars in fruit flesh of two pitaya species.

Pitaya species	Portion of flesh	Sugar content (mg/g of fruit flesh)[z] Glucose	Fructose	Sucrose	G/F[y]
White flesh	Peripheral part	64.3 ± 6.0	40.1 ± 3.7	7.5 ± 0.5	1.6
	Stylar-end part	89.3 ± 4.5	48.6 ± 3.4	6.2 ± 0.9	1.8
	Stem-end part	75.0 ± 3.5	50.1 ± 2.5	2.8 ± 0.6	1.5
	Core part	104.3 ± 13.2	64.9 ± 3.8	5.4 ± 0.3	1.6
Red flesh	Peripheral part	41.9 ± 4.3	32.3 ± 4.3	6.8 ± 0.7	1.3
	Stylar-end part	59.9 ± 3.4	42.8 ± 5.8	4.3 ± 0.8	1.4
	Stem-end part	48.6 ± 3.9	40.2 ± 3.0	2.9 ± 0.6	1.2
	Core part	68.1 ± 5.9	49.9 ± 5.1	4.2 ± 0.6	1.37

[z]Values are the means of triplicate determinations ± standard deviation.
[y]G/F indicated glucose to fructose ratio.

Table 3. Invertase activity in fruit flesh of two pitaya species.

Pitaya species	Portion of flesh	Protein conc. (μg/μl)	Invertase activity (n moles/min/mg/protein)[z] Acid invertase	Neutral invertase	Total invertase
White flesh	Peripheral part	0.041	5521	2054	7571
	Stylar-end part	0.066	5805	2875	8680
	Stem-end part	0.068	5701	2468	8169
	Core part	0.64	7208	2953	10161
Red flesh	Peripheral part	0.034	7396	1548	8944
	Stylar-end part	0.054	8722	2253	10975
	Stem-end part	0.031	7922	1295	9287
	Core part	0.048	10174	2761	12935

[z]Values are the means of triplicate determinations ± standard deviation.

Table 4. Amylase activity in fruit flesh of two pitaya species.

Pitaya species	Portion of flesh	Protein conc.	Amylase (n moles/min/mg/protein)[z]
White flesh	Peripheral part	0.041	6957
	Stylar-end part	0.066	7759
	Stem-end part	0.068	7211
	Core part	0.064	8711
Red flesh	Peripheral part	0.034	7626
	Stylar-end part	0.054	9626
	Stem-end part	0.031	8675
	Core part	0.048	10523

[z]Each value is the mean of at least duplicate samples.

species, but white species had the higher neutral invertase activity than that of red species. In both white and red pitaya, the core had the highest values in acid invertase and total invertase activities, followed the stylar-end, stem-end (except red neutral invertase), and peripheral parts.

The measured amylase activities are presented in Table 4. The amylase activity in the stylar-end was not higher than in the core, despite that the glucose to fructose ratio was higher in the stylar-end than in the core. This may be explained by the differences in the ratio of invertase activity and amylase activity between that the stylar-end and the core parts. From data in Tables 3 and 4, the ratio of stylar-end to core part in invertase activity was 0.85 and 0.85 in white species and red species, respectively. Whereas, the ratio of stylar-end to core parts in amylase activity was 0.89 and 0.91 in white species and red species, respectively. The higher amylase activity implied the larger amount of the glucose accumulation, so the ratio of glucose to fructose in stylar-end will be higher than in the core part. The higher ratio of the glucose to fructose indicated that the amylase played an important role in the hydrolysis of starch for the accumulation of hexose in pitaya fruit.

In conclusion, for both white and red pitaya, the distribution of soluble solids content in the fruit were in the descendent order: the core, stylar-end, stem-end, and peripheral parts. The major soluble sugars in the pitaya are glucose, fructose, and sucrose. The distribution of sugars in various parts of the fruit was closely related to different enzyme activities. The high ratio of glucose to fructose in all parts of the fruit indicated the hydrolysis of starch by amylase. The results suggest that amylase plays an important role in the accumulation of glucose in pitaya fruit.

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